LANdroids

BAA 07-46

Bidders Day Briefing

July 6, 2007

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Being In The Right Place Is Key So Move There!

Read the BAA.

This briefing is NOT a replacement for the BAA.

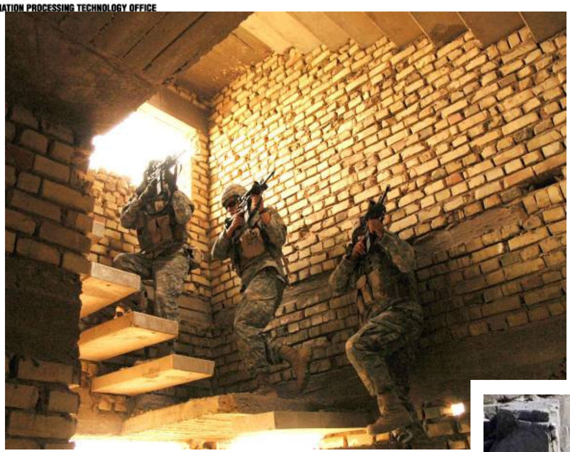
In the event of a discrepancy between the material shown here and the LANdroids BAA, or the FedBizOpps announcement, the BAA / announcement takes precedence.

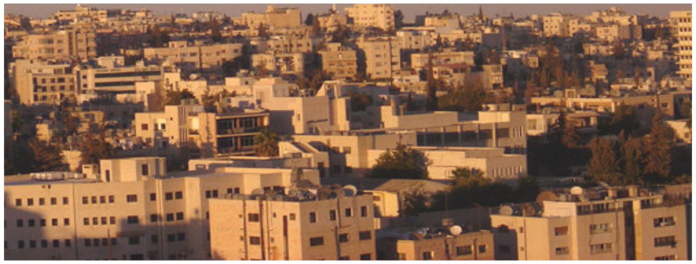
This briefing will be posted to the IPTO solicitations webpage -- www.darpa.mil/ipto/solicitations

Email questions to baa07-46@darpa.mil.

Motivation

Motivation





Not just multipath fading –
shadows, need more range, etc.

Good places for cover are typically
bad places for comms.

Urban & NLOS operations common.
Comms increasingly more important.

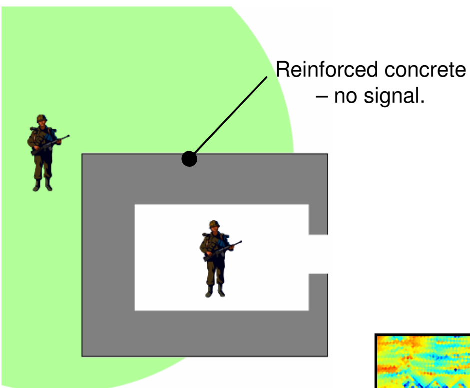
Digital comms needed everywhere –
voice, sensors, etc.

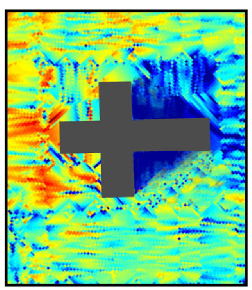
Only the weapons work <u>reliably</u> in places like these.

Soldiers Need Communications In/Between Buildings, Structures, Terrain

Overview

- **Problem:** Urban & NLOS settings hinder comms – ***no reach back for warfighters.***
- **Goal:** Effective comms that can be deployed as our warfighters deploy.
- **Key Observation:** Location greatly impacts comms.
- **Approach:** **LANdroids – small, inexpensive, smart robotic radio network relay nodes**.
  – Warfighters drop as they go.
  – Nodes coordinate & move autonomously to **optimize comms & battery life**.
- **Result:** Self-configuring, self-optimizing, self-healing, rapidly deployable mesh radio networks.

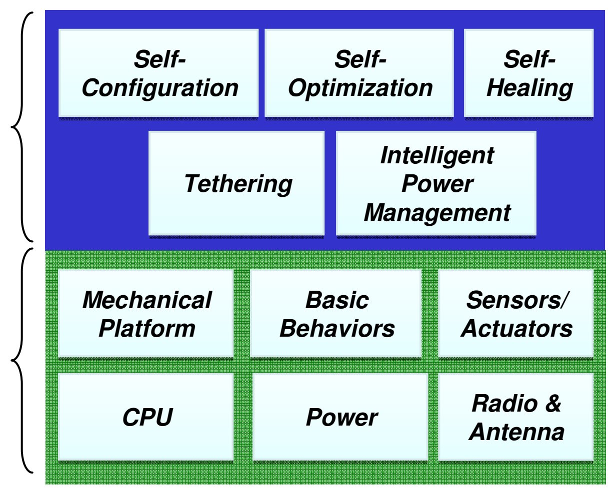




LANdroid Architecture

Task A: Autonomous Intelligent Control Layer

Task B: Underlying low-cost, low-power, robust platform



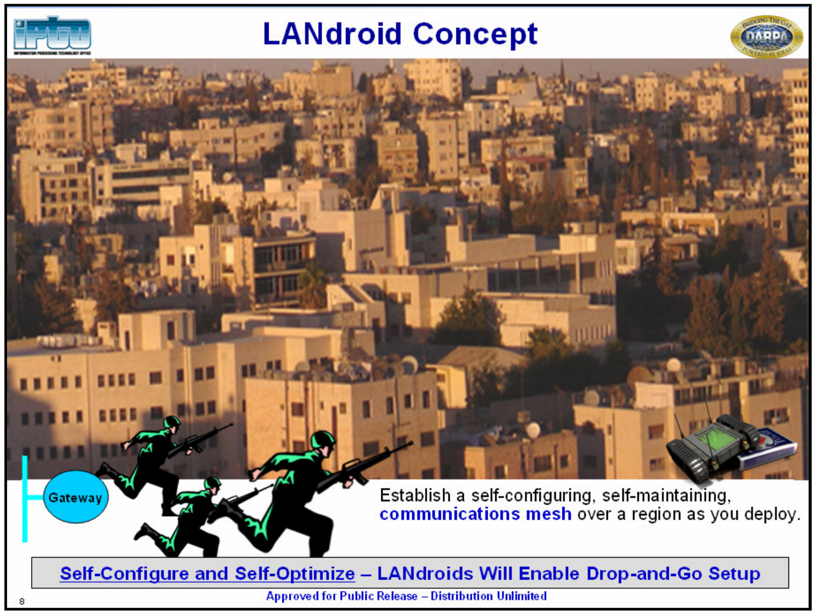
Location matters! Movement buys a lot.

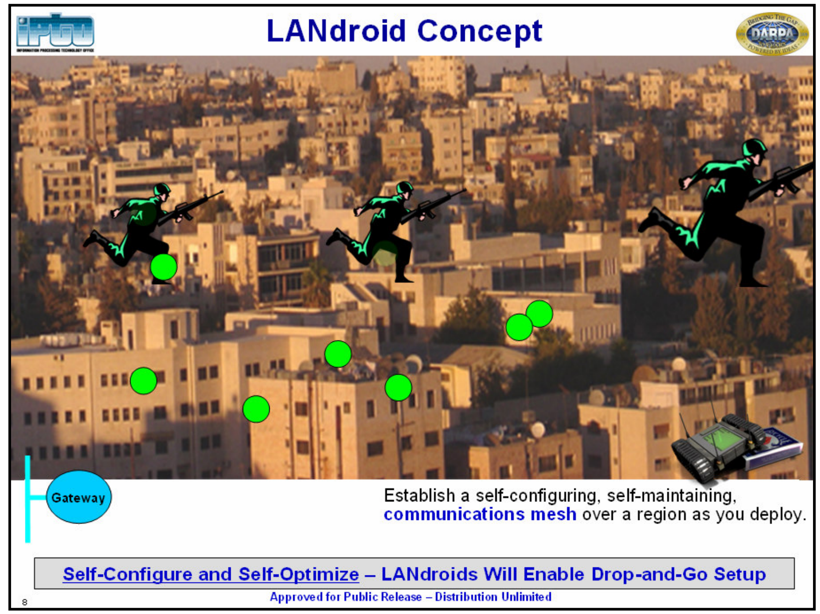
LANdroids – small, inexpensive, **smart** robotic relay nodes.

Being In The Right Place Is Key So Move There!

Approved for Public Release – Distribution Unlimited

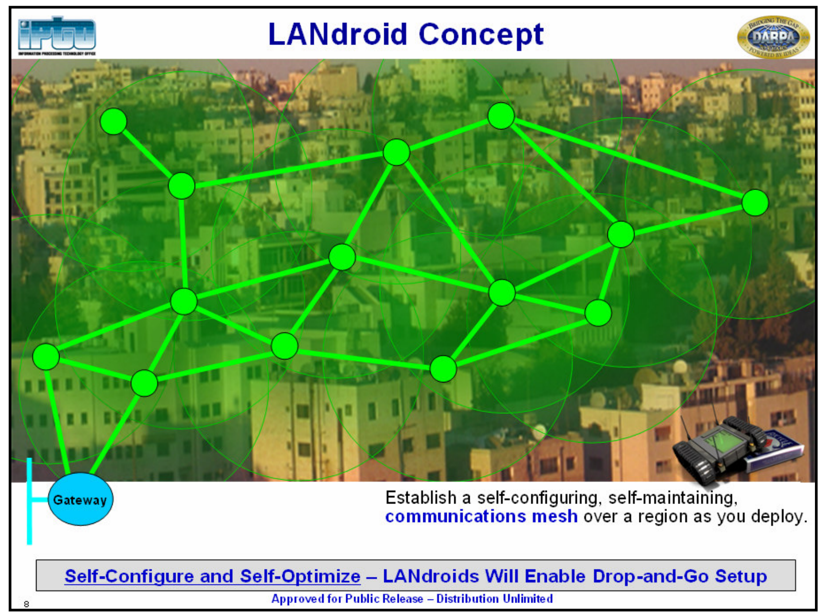
LANdroid Concept



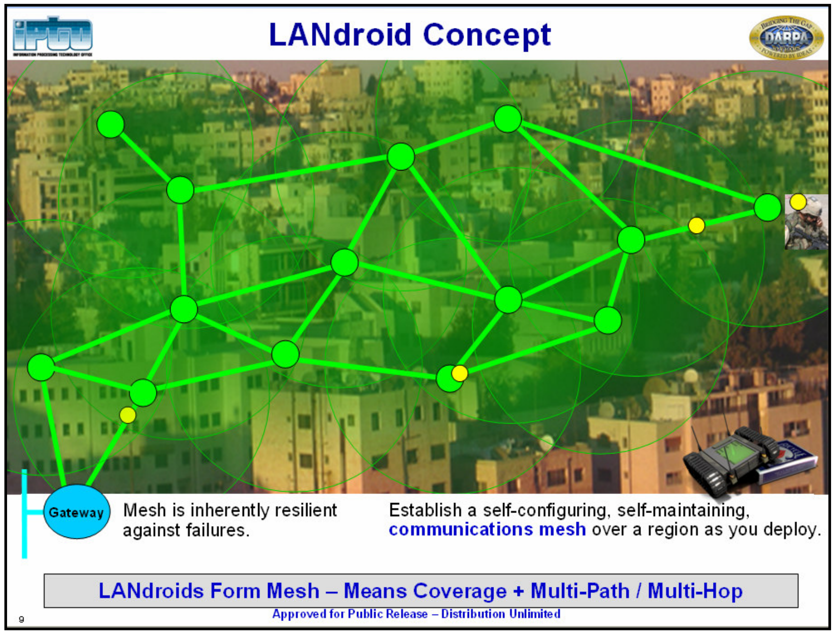


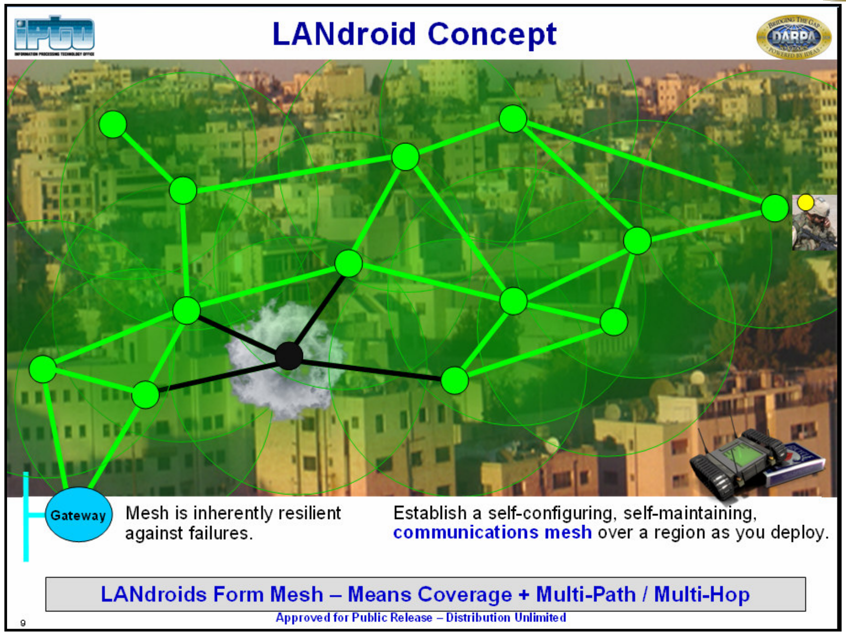
(Flow is from upper left to upper right to lower right.)

The concept is that warfighters will carry multiple LANdroids and will deploy them as they move through the region. The LANdroids will then *self-configure* and establish a mesh network over the region. This means that the initial set of warfighters have effective communications in said region and that subsequent warfighters moving through the same region also have communications.



LANdroid Concept





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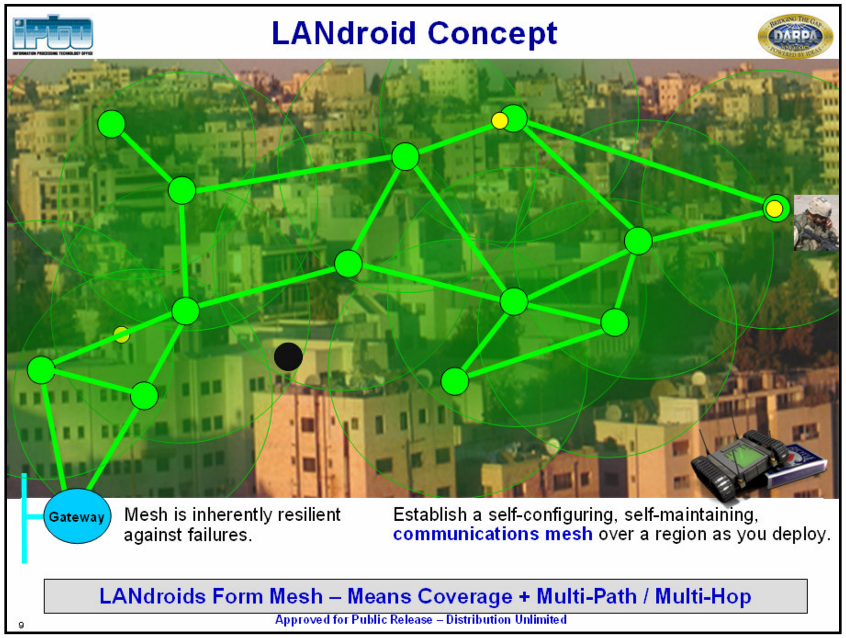
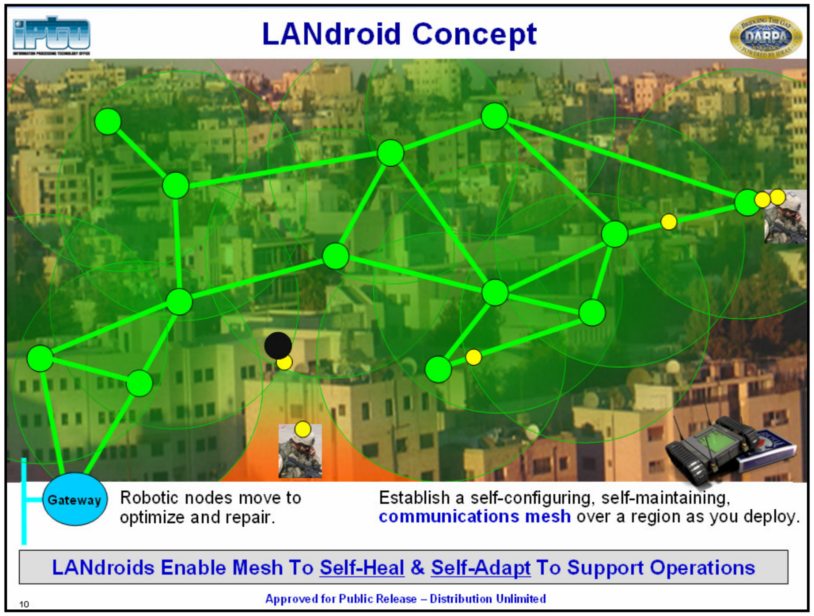
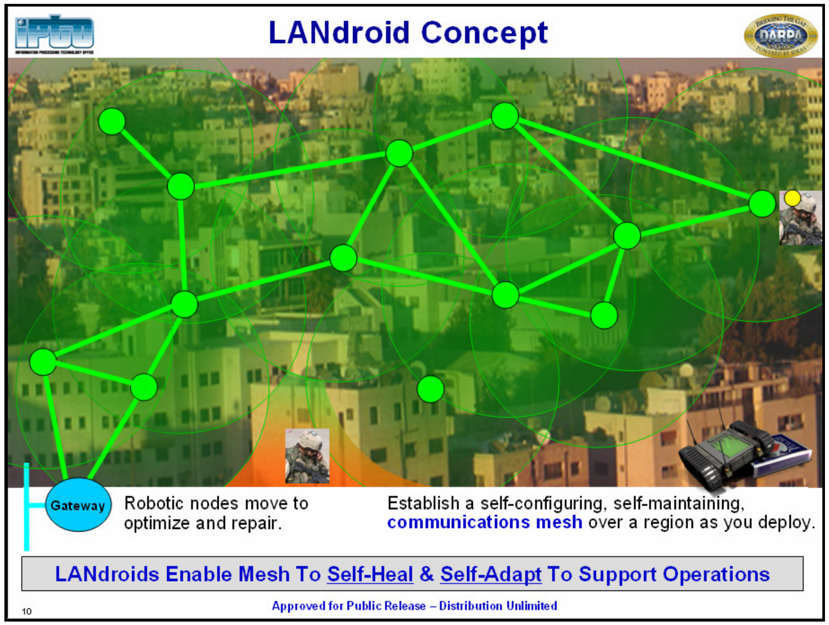
The advantage of mesh networks is that they are generally multi-path and multiply connected. This means that if a node is destroyed, packets can generally take an alternative route.



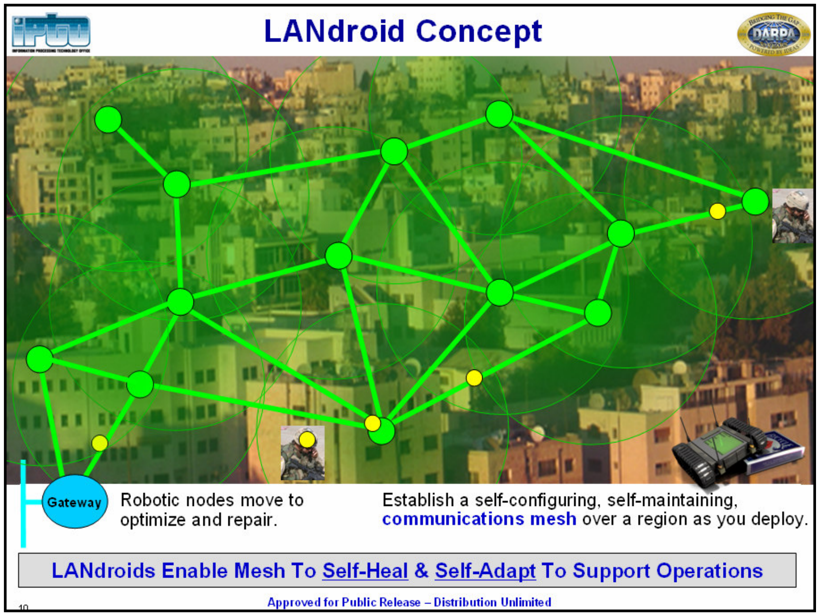
LANdroid Concept



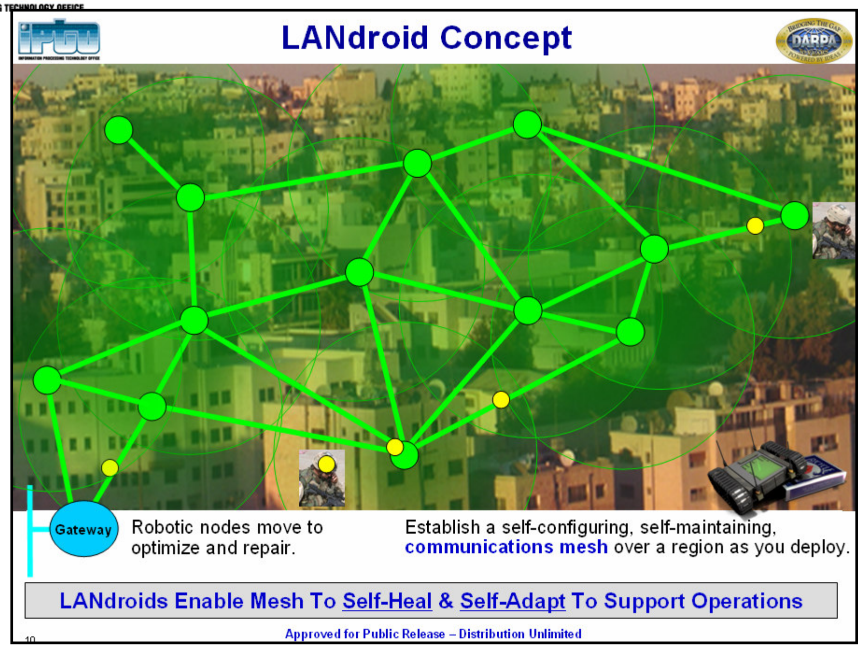


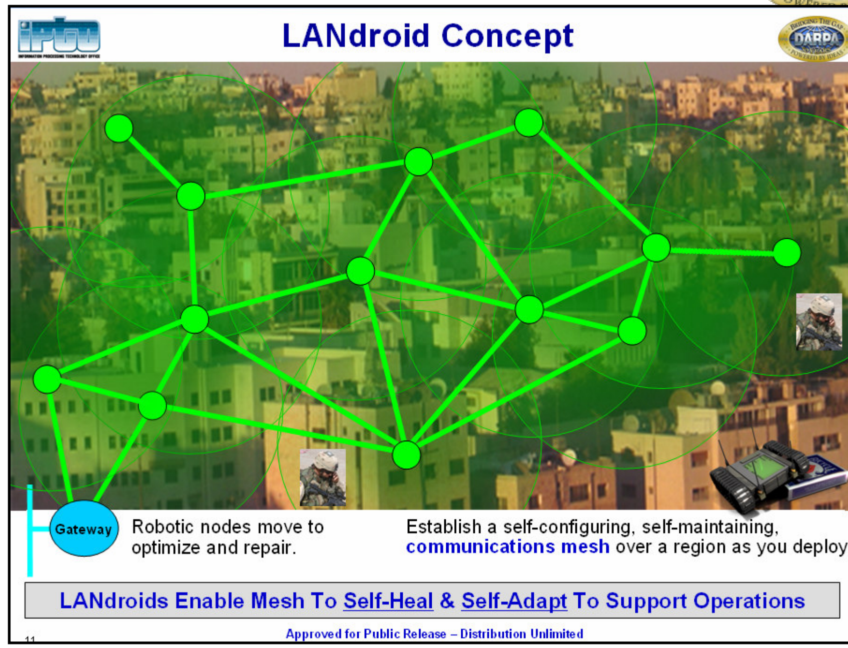
(Flow is from upper left to upper right to lower right.)

With a conventional static relay node, a warfighter who moved into the region in which the node was destroyed might not have communications. With LANdroids, movement can be exploited to *self-heal* the network (nodes adjust to cover the region).



LANdroid Concept





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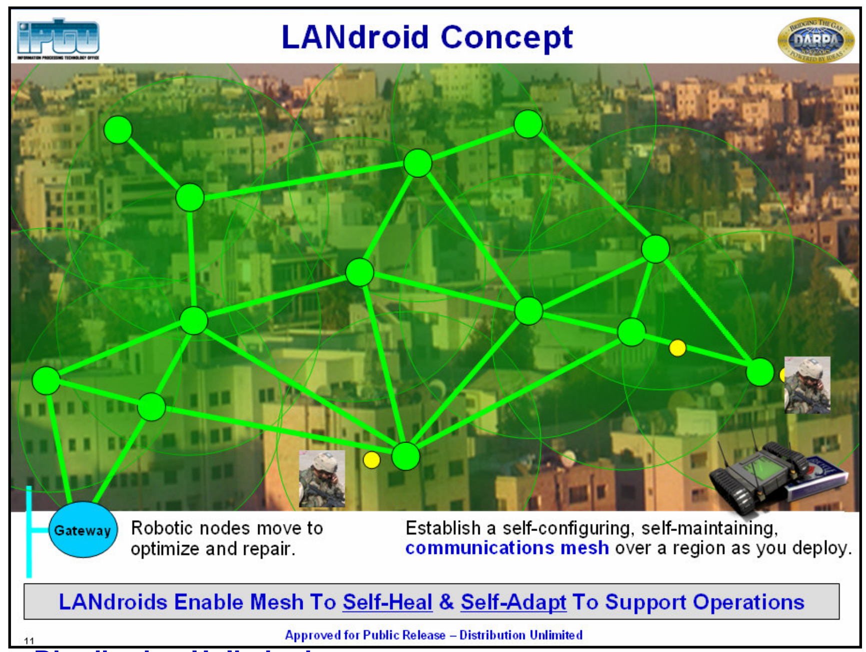
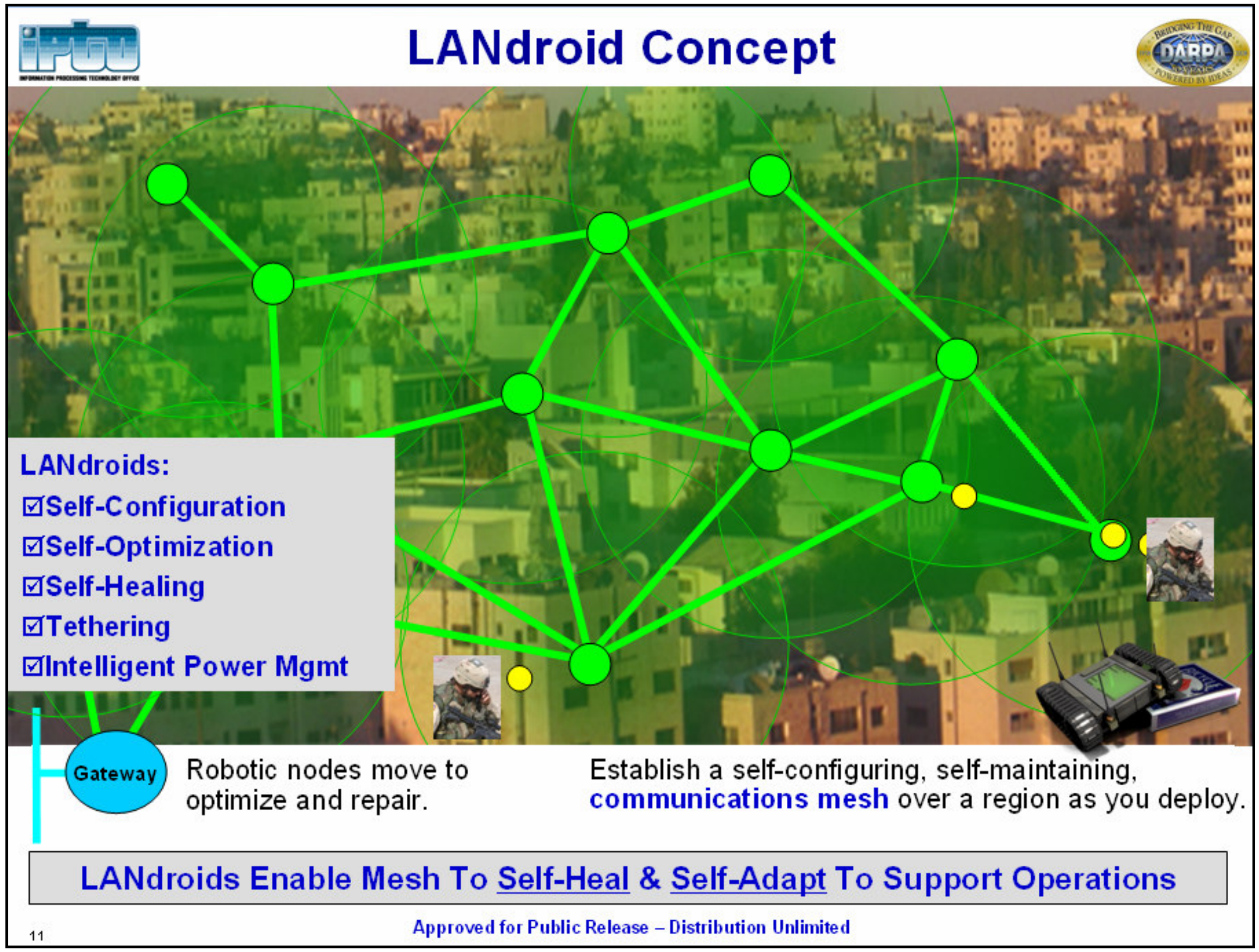
Movement can also be exploited to create *tethering* – which is having the network stretch or adjust to keep warfighters covered with communications as they move.

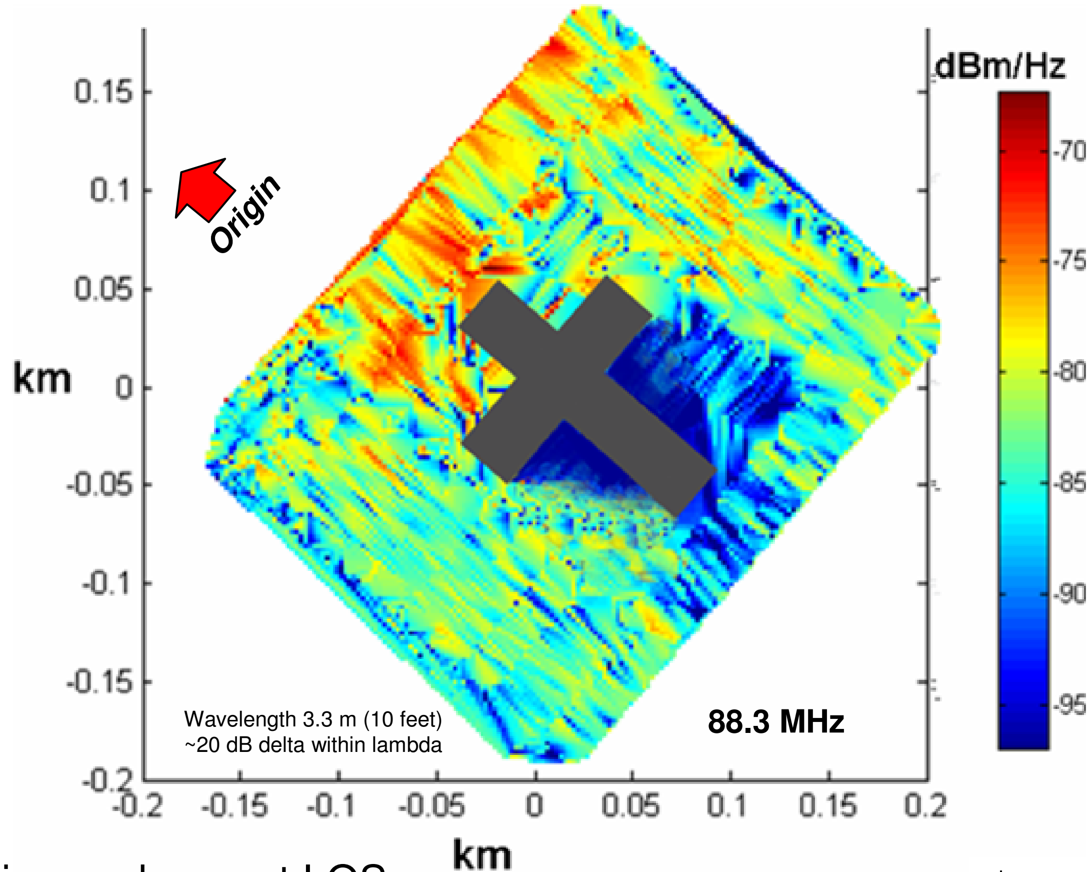


LANdroid Concept

The goal is to exploit movement to create these properties.



The Core Problem – NLOS Settings Block Comms



This is a simple outdoor example – same problem indoors.

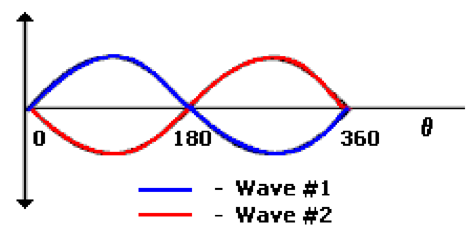
<u>The general concept is ubiquitous.</u>

- Energy transmission works great LOS.
- NLOS in urban settings, caves, etc.
  - Absorption
  - Reflection
  - Refraction
  - Diffraction

Energy loss.
Multi-path fading.
Shadows.

$$\text{Wavelength} = \frac{\text{Speed of Light}}{\text{Frequency of Oscillation}}$$

$$\text{Frequency of Oscillation} = \frac{\text{Speed of Light}}{\text{Wavelength}}$$



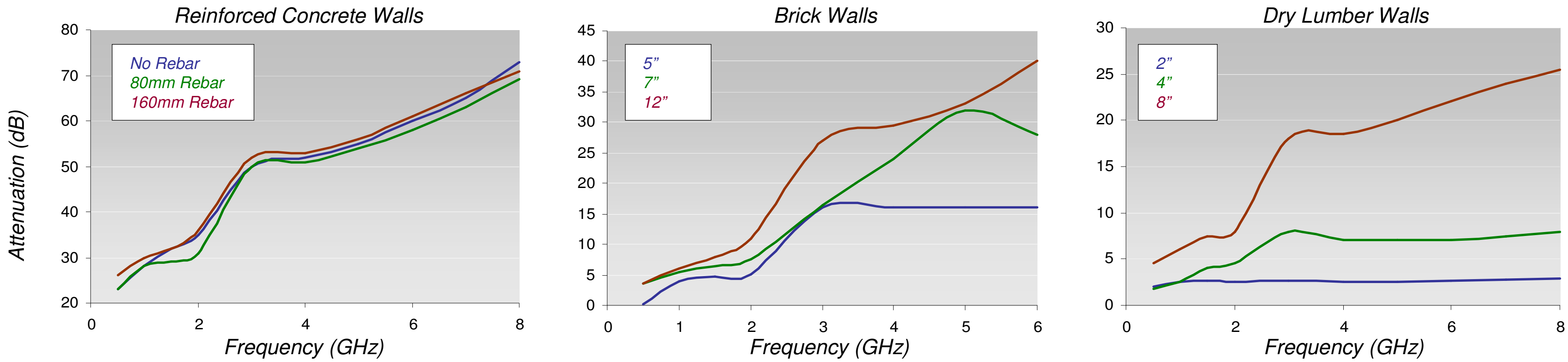
Even when signals get through, multi-path fading occurs.

Obstacles Absorb and Reflect Energy – Comm Signals Don't Get Through

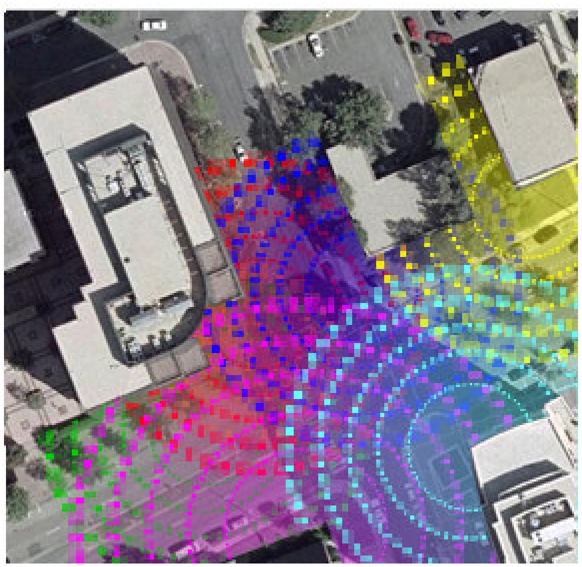
Complex Characteristics Highly Situation Specific

Signal Attenuation in Different Materials

(Loss dB)



At 2 Ghz ~35 dB loss in RC walls, ~5-12 dB loss in brick walls, and ~3-7 dB loss in lumber walls.



- Urban/NLOS settings mean complex signaling.
  - –Different materials have different properties, thickness & angle of incidence matter, etc.
- Very **difficult to predict** interplay of reflection, refraction, energy loss, etc.

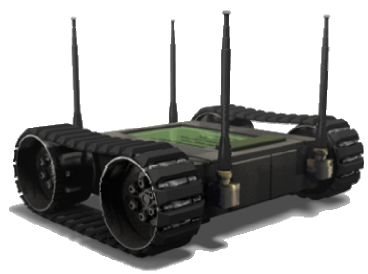
Hard to Pre-Determine Exactly Where to Put Relays

Manual Measure and Test

The conventional approach ⮥ won't work well in combat ⮥

• Conventional = place with great care.

Move!

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Air Force Memorial Interferes With Police, Fire Department Radios

WRC-TV
3:55 p.m. EDT June 16, 2006

ARLINGTON, Va. - A new Air Force memorial is causing trouble for emergency crews in Arlington County. At 170 feet high, the tallest of three steel spires blocks the signal for portable radios used by police and firefighters.

The problem is at its worst in the Crystal City area near Reagan National Airport. Extra patrols are now

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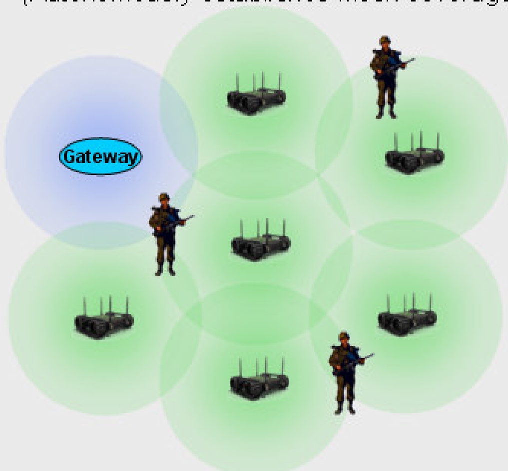
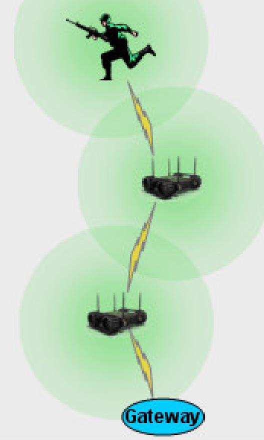
Location, Location, Location Matters & "Good Locations" May Change

Autonomous Movement Gets You…

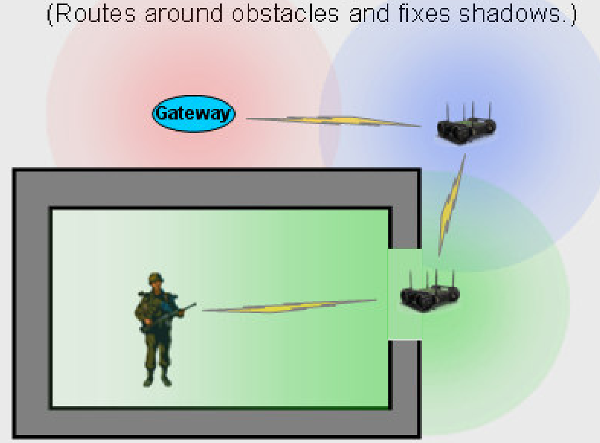
Self-Configuration
(Autonomously establishes mesh coverage)



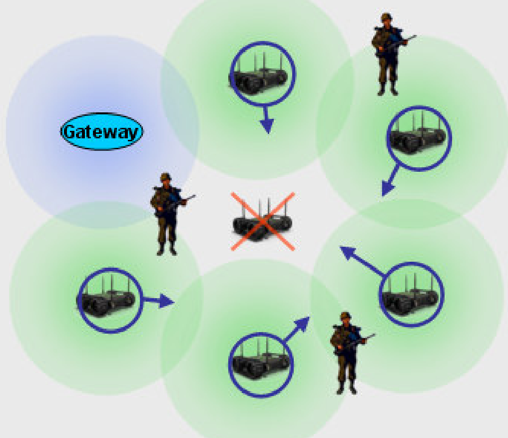
Tethering
(Dynamic range extension flexes the mesh as needed)



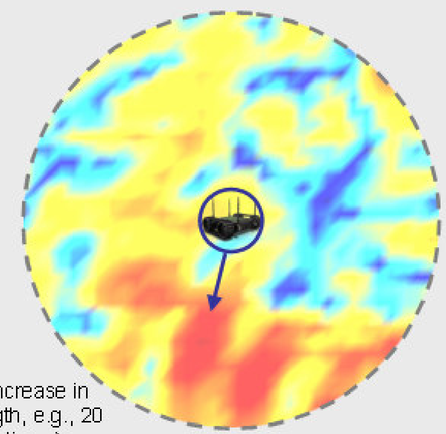
Tethering = Intelligent Relaying
(Routes around obstacles and fixes shadows.)



Self-Healing
(Intelligently recovers from node failure)



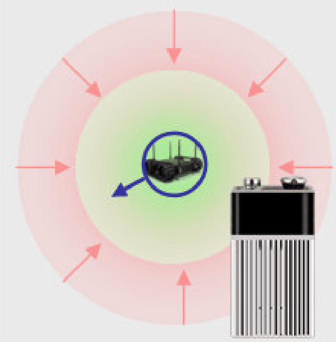
Self-Optimizing
(Optimizes signal in multi-path fading environment)



Dramatic increase in signal strength, e.g., 20 dB (100 times)

Intelligent Power Management

- *Maximize longevity*
- *Move to minimize Tx power*



Being In The Right Place Is Always Key – So Move There!

Mutually Complementary Technologies

Autonomous Movement – 10-20 dB

Program Focus

Antenna Orientation – 8-16 dB

Antenna Diversity (MIMO)– 5-12 dB

Antenna Polarization – 3-12 dB

Null Steering/ Beamforming – 3-10dB

Not Our Focus – These Enhance Movement & Vice Versa

Many focused on multi-path fading.

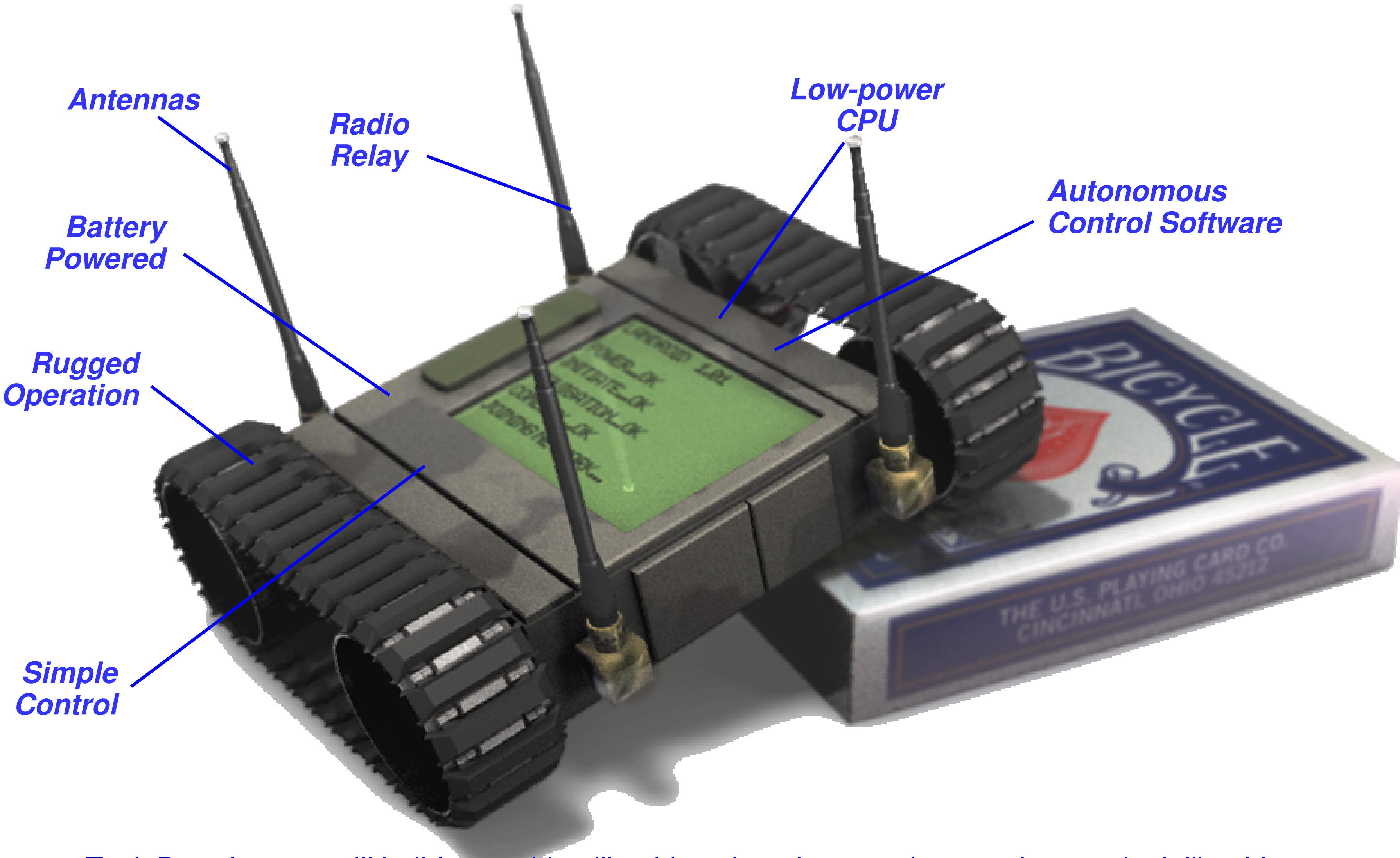
Movement also gets you self-configuration, self-healing, tethering, etc.

Other technologies generally assume radio can't control its location.
LANdroids CAN control their location.

Numbers are estimates and may be approximate.

Other Complementary Advances Can Be Added To Moving LANdroid Platforms

Example Deployable LANdroid Solution

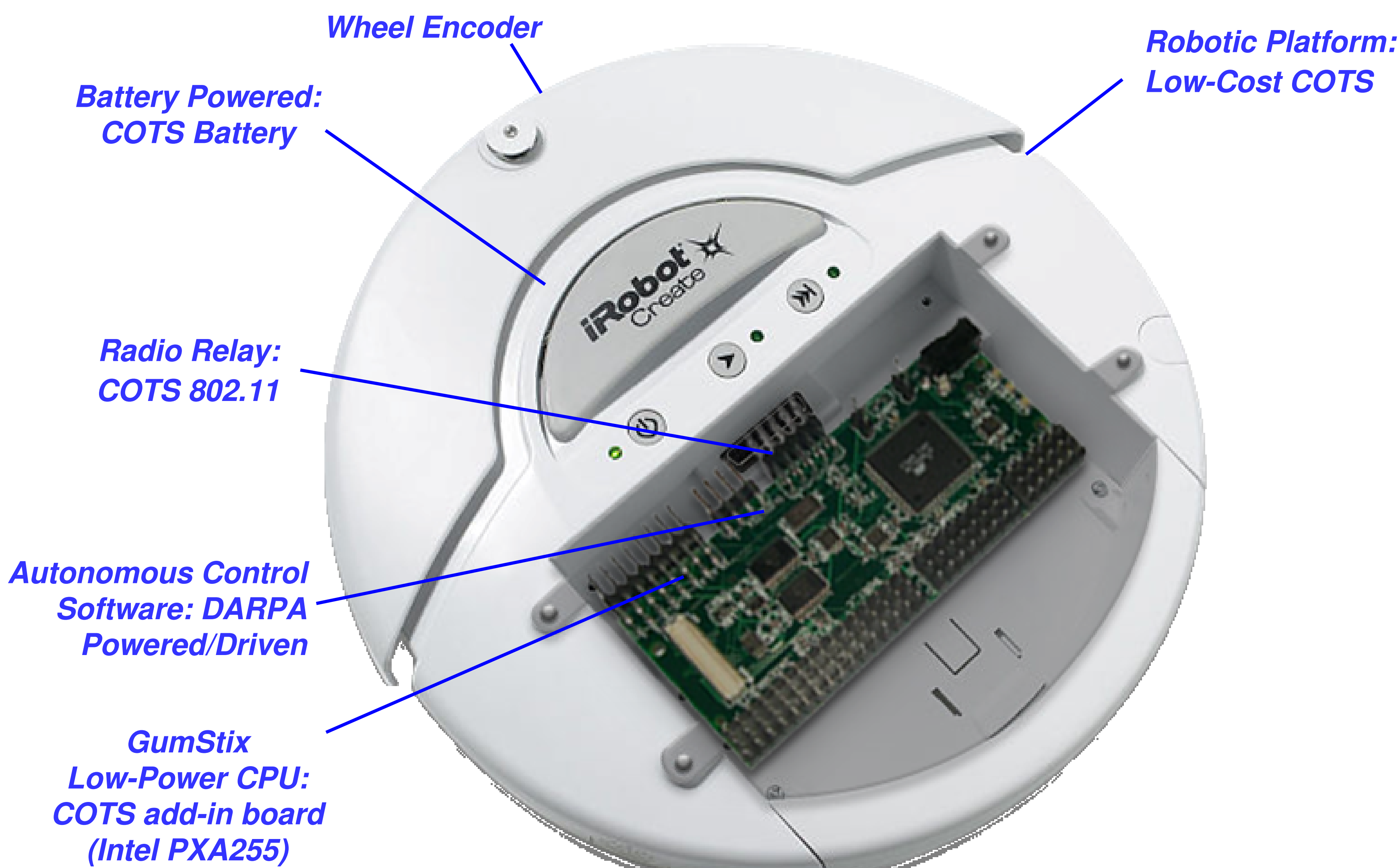


Task B performers will build something like this – though yours does not have to look like this.

One Possible Vision Of Deployable LANdroid – Small, Inexpensive, Effective

Possible Research Prototype Platform

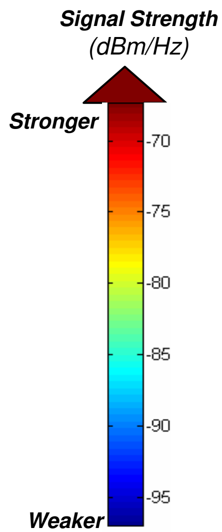
- Platform's CPU / sensor limitations may be realistic relative to deployed system.

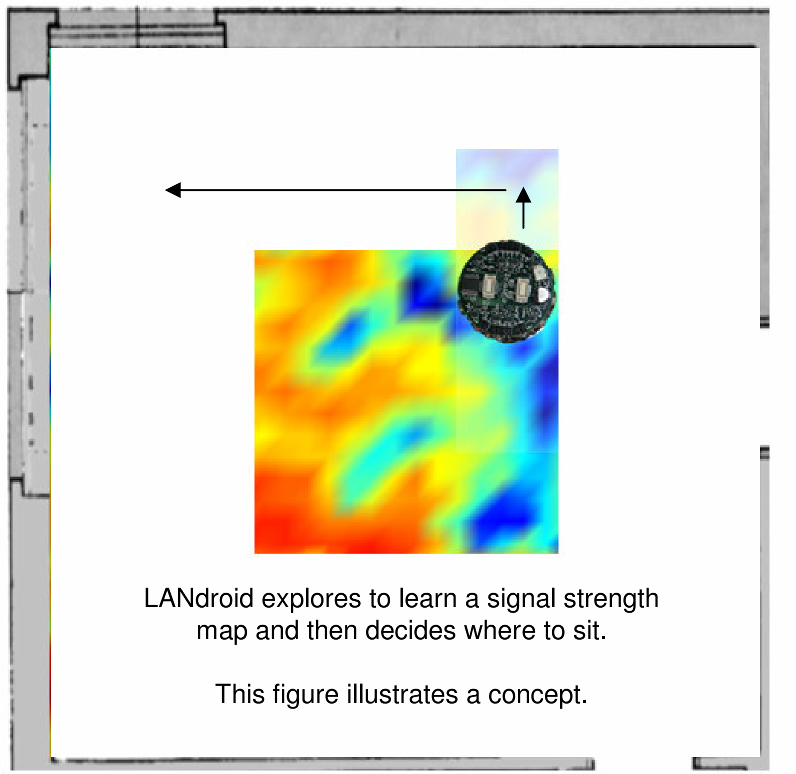


Task A Performers May Start Out With Something Like This

One Potential View of a Simplified LANdroid Control Problem

- Decide where to sit to maximize signal strength & save power.





Simplified Example: assumes static single source and static world.

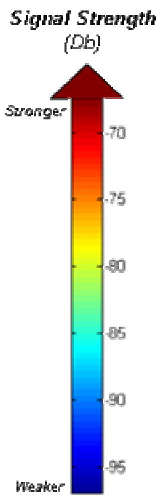
Source

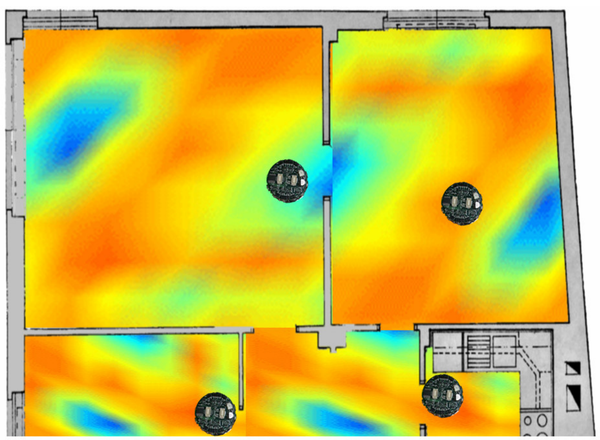
This is an illustration.

The Signal Itself Is An Important Sensor

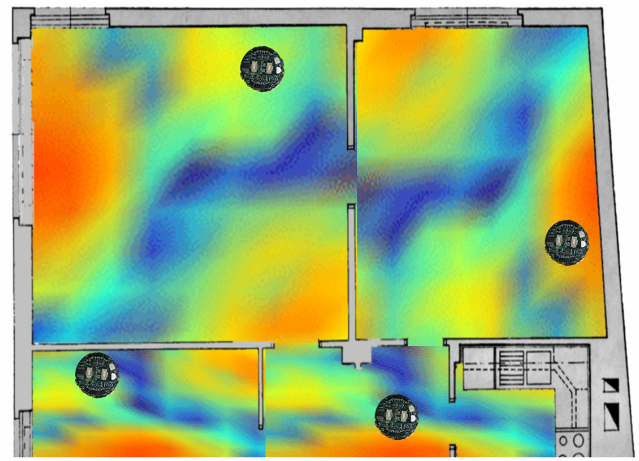
A Less Simplified Version

- LANdroids are interdependent / need to work together.
- Choices made by one LANdroid may impact others.





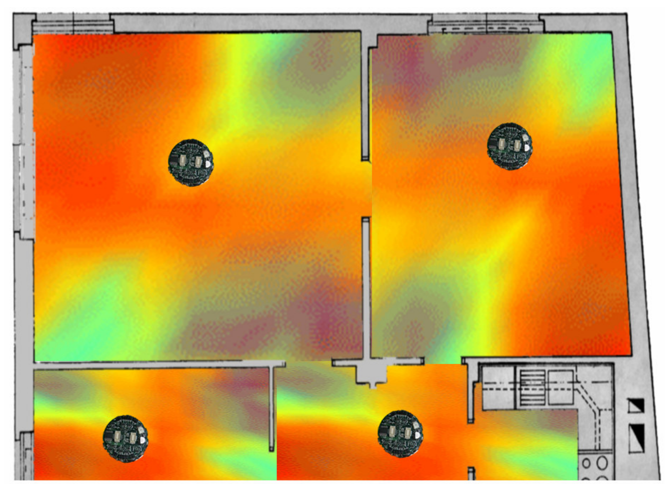
Time X



Time X+Y

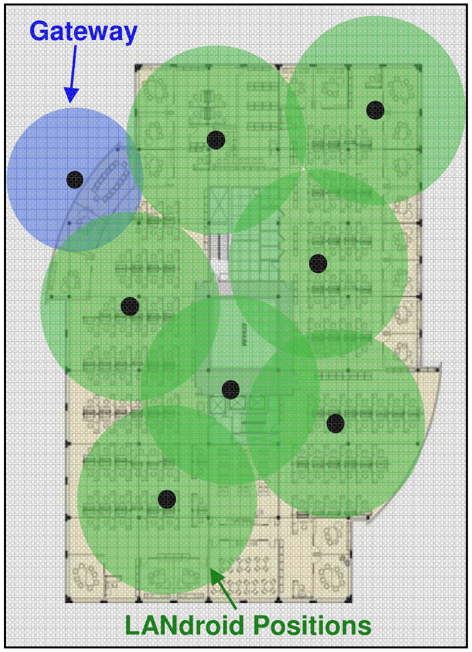
These figures illustrate a concept.

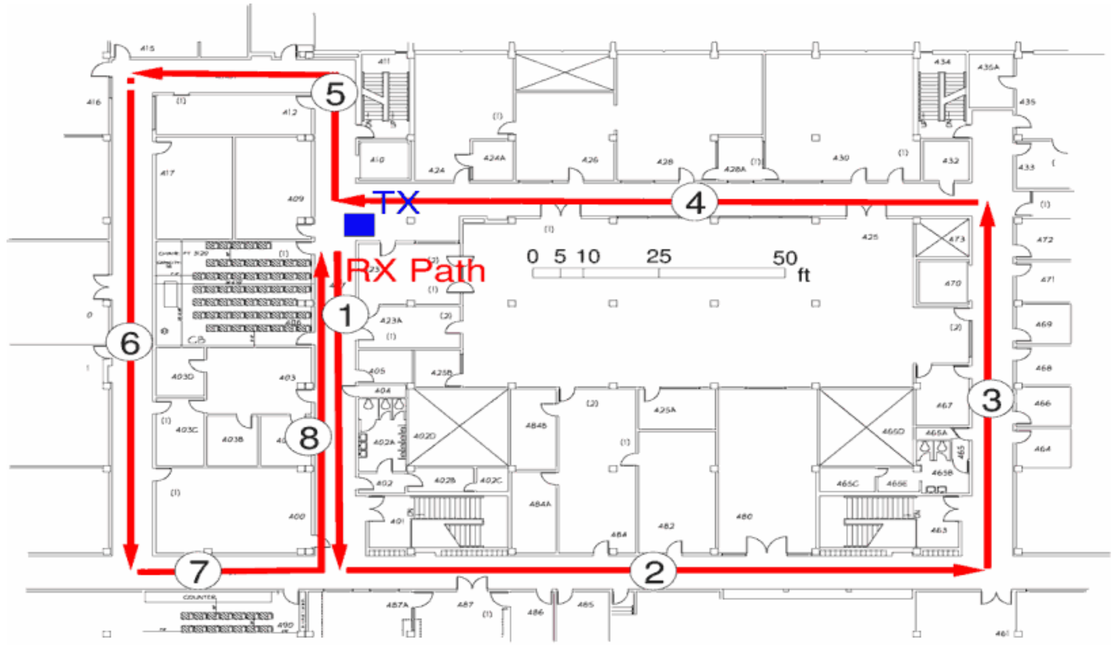
If LANdroids that are close to each other are moving at once, one *may* see the signal maps changing in unexpected ways because the building materials between the LANdroids are changing, the angles are changing, etc. When a LANdroid comes back to the same position it was in a moment ago, the signal strength map *may* look different than it did earlier under these circumstances because everyone is moving at once.



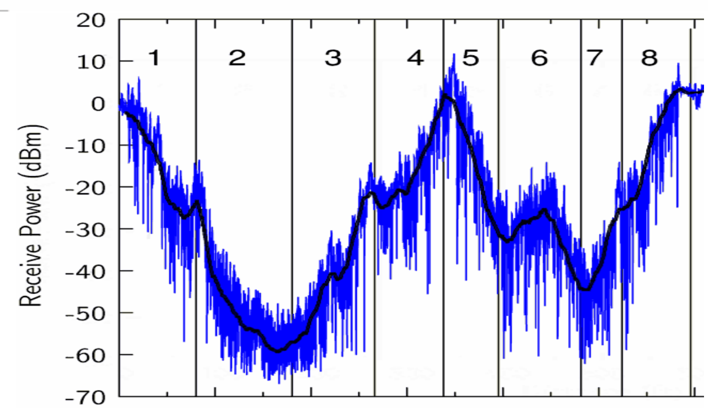
Time X+Y+Z

Properties Over Larger Distances





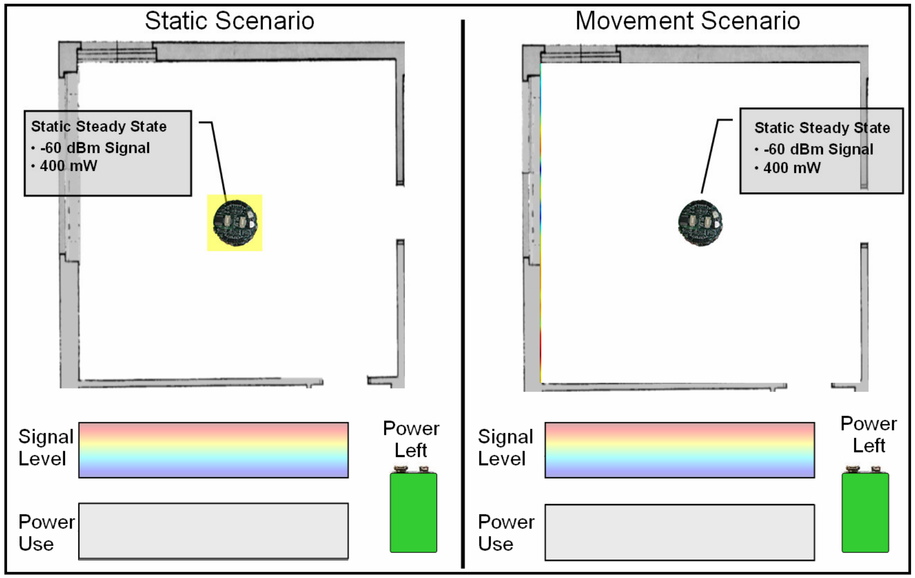
Movements "in the large" may exhibit trends.

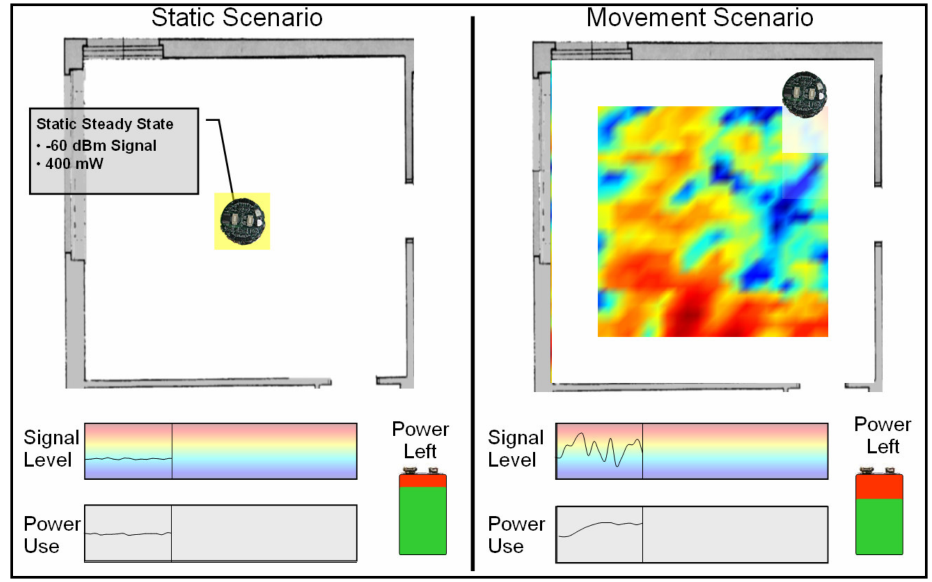


Numbers may be notional.

Control Problem May Encompass Both Small and Large Distances

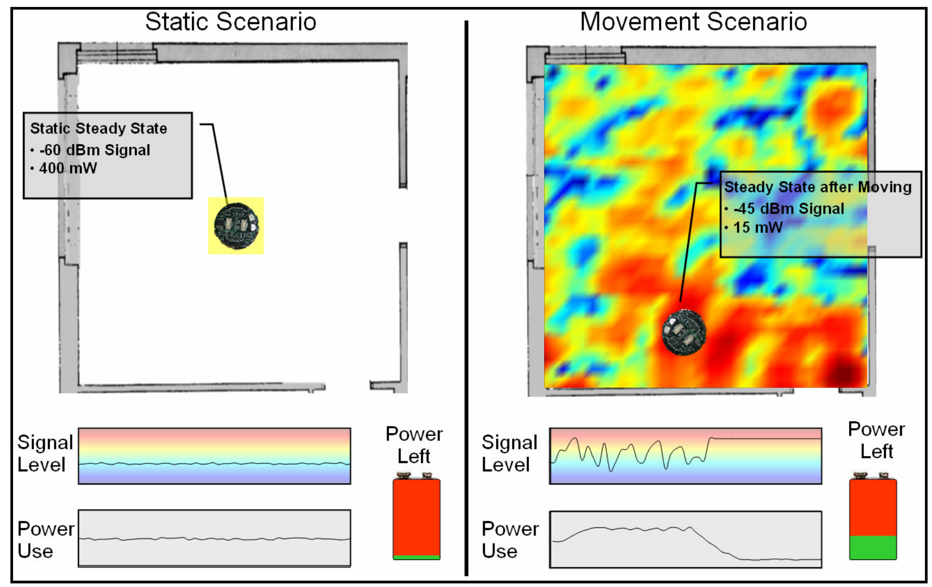
Spending Power To Move Can Save Power





These figures illustrate a concept.

In the starting position (upper left) the two LANdroids are in the same initial state. However, one LANdroid decides to move (upper right) and explores to learn the signal strength map. Having learned the signal strength map (lower right) it may be able to find a location in which to sit that enables it to turn down the power on its radio so that over time its power actually lasts longer.



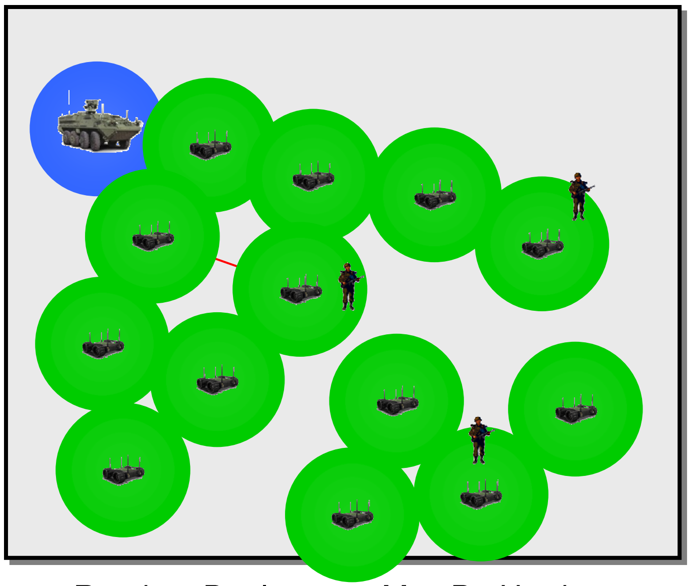
Numbers may be notional.

A Small Investment of Energy to Move Can Pay Off In The Long Run

Possible Deployment Models

- Random or Ad-Hoc:
  - May not be connected initially.
  - May not have a node count.
  - May be hard to detect isolated subnets.
  - Control algorithms may be less informed.

- Placement-by-Indicator:
  - May improve odds of initial connection.
  - May improve odds of node count.
  - May make it easier to identify isolated subnets.
  - Control algorithms may be more informed.



Random Deployment May Be Harder

Smarter Deployment – Placement-by-Indicator

Your Solution Should Support Both Models

Geolocation

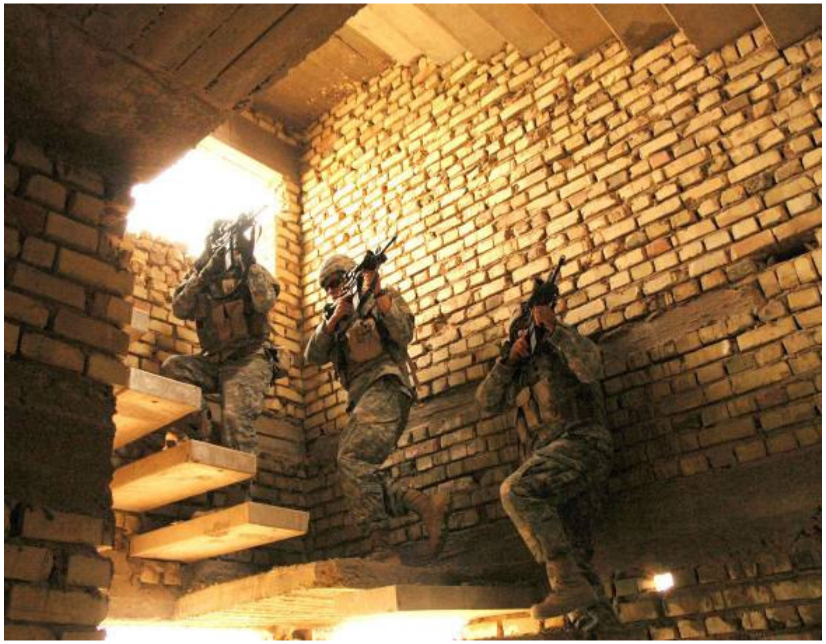
- Spectrum of possibilities.

- One end – weakly informed:
  - No strong knowledge of surroundings.
  - No absolute location information.
  - Must rely on local sensors.
  - Knows where it is relative to where it was dropped, e.g., wheel encoders.
  - This is the model envisioned for LANdroids (small, inexpensive, and not requiring large amounts of knowledge or pre-programming).

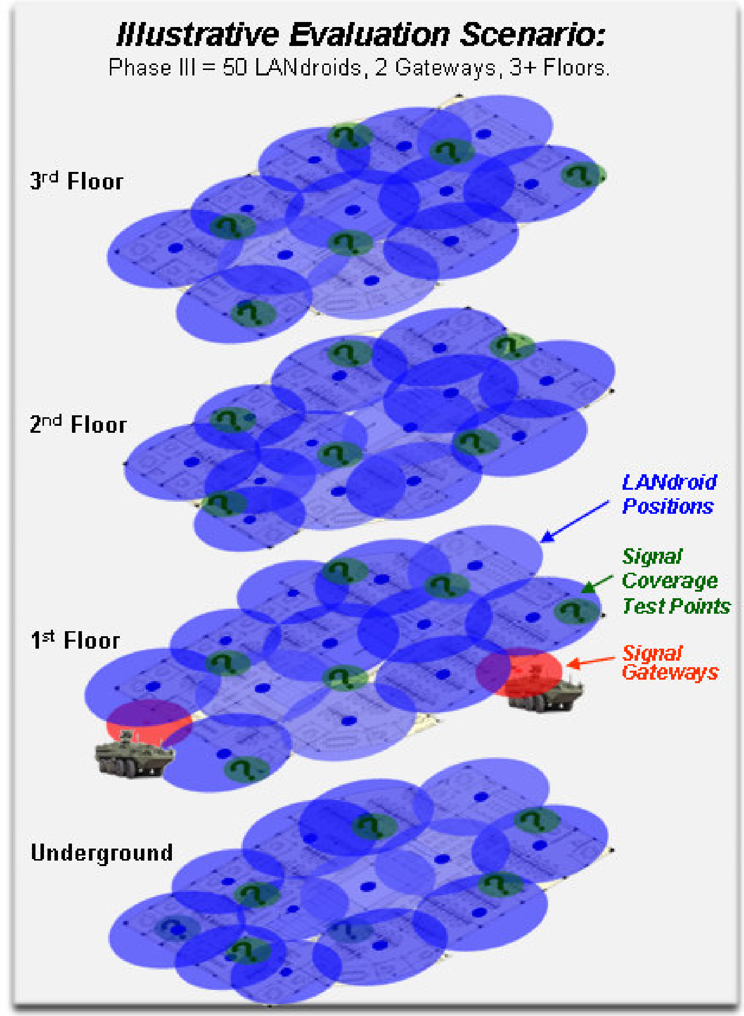
- Other end – ?
  - You can propose enhancements to this model or alternative models that are within the spirit of small, inexpensive, and smart.

Movement

- Warfighter provides primary movement.
  - LANdroids are a communications solution that incorporates both node density and movement.
- LANdroids probably do not need to climb rocks or stairs.
  - You can still propose a more adept solution.



Programmatics – Environment



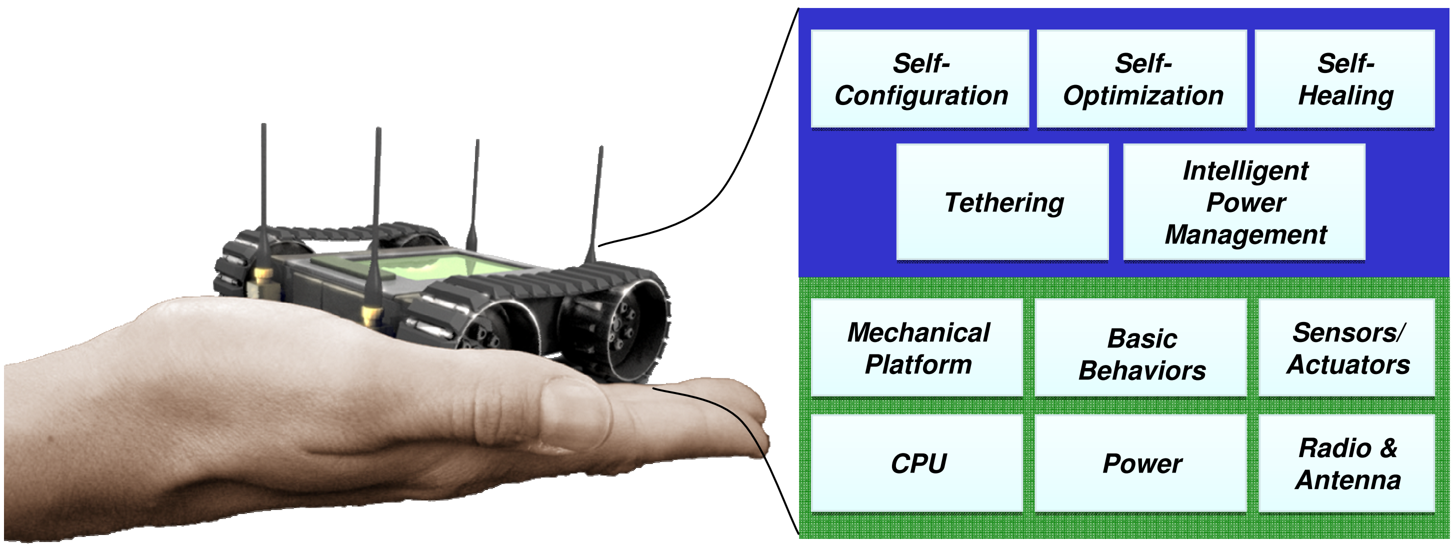
Indoors – Initial domain for research:

- Building clearing TTP.
- Task B may see other settings as well.

- Program emphasis is urban settings.

For Technology Development: Indoors – Multiple Floors

Programmatics – Two Technical Tasks and Two Evaluation Tasks



Task A:
Autonomous Intelligent Control Layer

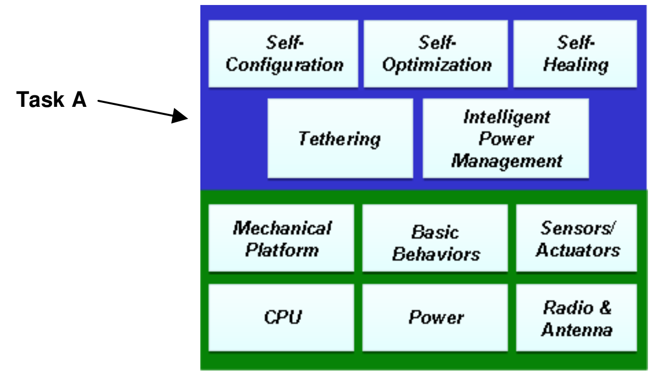
Task B:
Underlying low-cost, low-power, robust platform

Task A – LANdroid Control Software.
Task C – Evaluation of Control Software.

Task B – LANdroids Robot Development.
Task D – Evaluation of Robots.

Task A – LANdroid Control Software

- Develop algorithms necessary to implement the capabilities listed previously:
  - Self-configuration.
  - Self-optimization.
  - Self-healing.
  - Tethering.
  - Intelligent power management.



- May want to consider incorporating:
  - Coordination of LANdroid decision making.
  - Local reasoning to support desired properties, e.g., self-healing.
  - Robotic behaviors to enact desired properties.

- This list is not complete or exhaustive.

- ***A wide range of solutions are possible and encouraged.***

This is a subset of the information in the BAA.

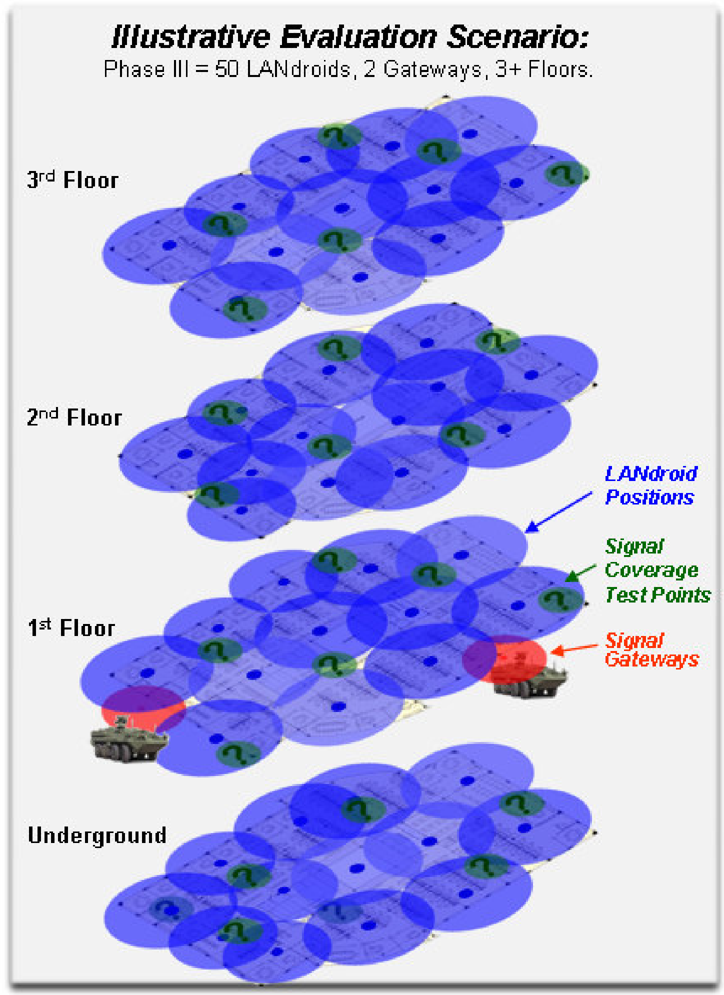
- Task A performers will use government specified robotic platforms to support comparison across efforts, e.g., *gumstix* + iRobot Create or something comparable.
  - You may suggest additional low cost, low power sensors.

Create The Software to Support LANdroids Concept & Run on a Lightweight Platform

Task C – Evaluation of LANdroid Control Software

- Expertise should include understanding of radio signals and communications.

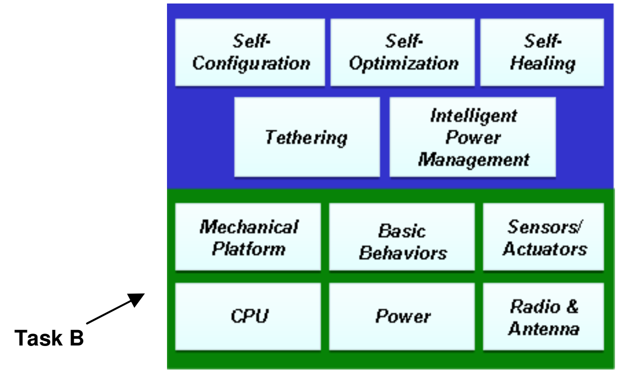
- Duties include but are not limited to:
  - Designing test scenarios and evaluation plans.
  - Locating and securing a proper site(s) for testing.
  - Defining an auto deployment surrogate, e.g., signal strength meter.
  - Assisting in selection of a MANET protocol for Task A during Phase 1.
  - Conducting pilot and end-of-phase evaluations.
  - Supplying all necessary equipment for evaluation measurement.
  - Reporting results to DARPA.



This is a subset of the information in the BAA.

Task B – LANdroids Robot Development

- Focus on the robotic platform and novel combinations of existing technologies, e.g., antennas, power, radio, etc.
- **A wide range of solutions are possible – including a highly specialized and possibly limited platform.**
- **Keep in mind: *small, inexpensive, intelligent, and disposable communications relays.***



- Fundamental platform requirements:
  - Size, e.g., ~1,000 cm^3 and ~1,000 grams (~2.2lbs).
  - Robust – sufficiently rugged, e.g., shock, vibration, temperature, dust, humidity, if not necessarily MILspec.
  - Inexpensive, e.g., $100 end unit cost.

- Basic capability requirements:
  - Movement – at least 0.5m/sec (~1mph) over a typical indoor environment, e.g., concrete, asphalt, carpet.
  - Simple behaviors, e.g., detect obstacle and halt.
  - Basic “dead reckoning” navigation also desired (add appropriate sensors).
  - Power for movement, onboard radio, and processor running control algorithms.
    - Need to be able to report power to the control algorithms.

- Platform payload requirements:
  - Processor module – low-power but “enough.”
  - Radio relay module – 802.11 but not narrowly engineered around this.

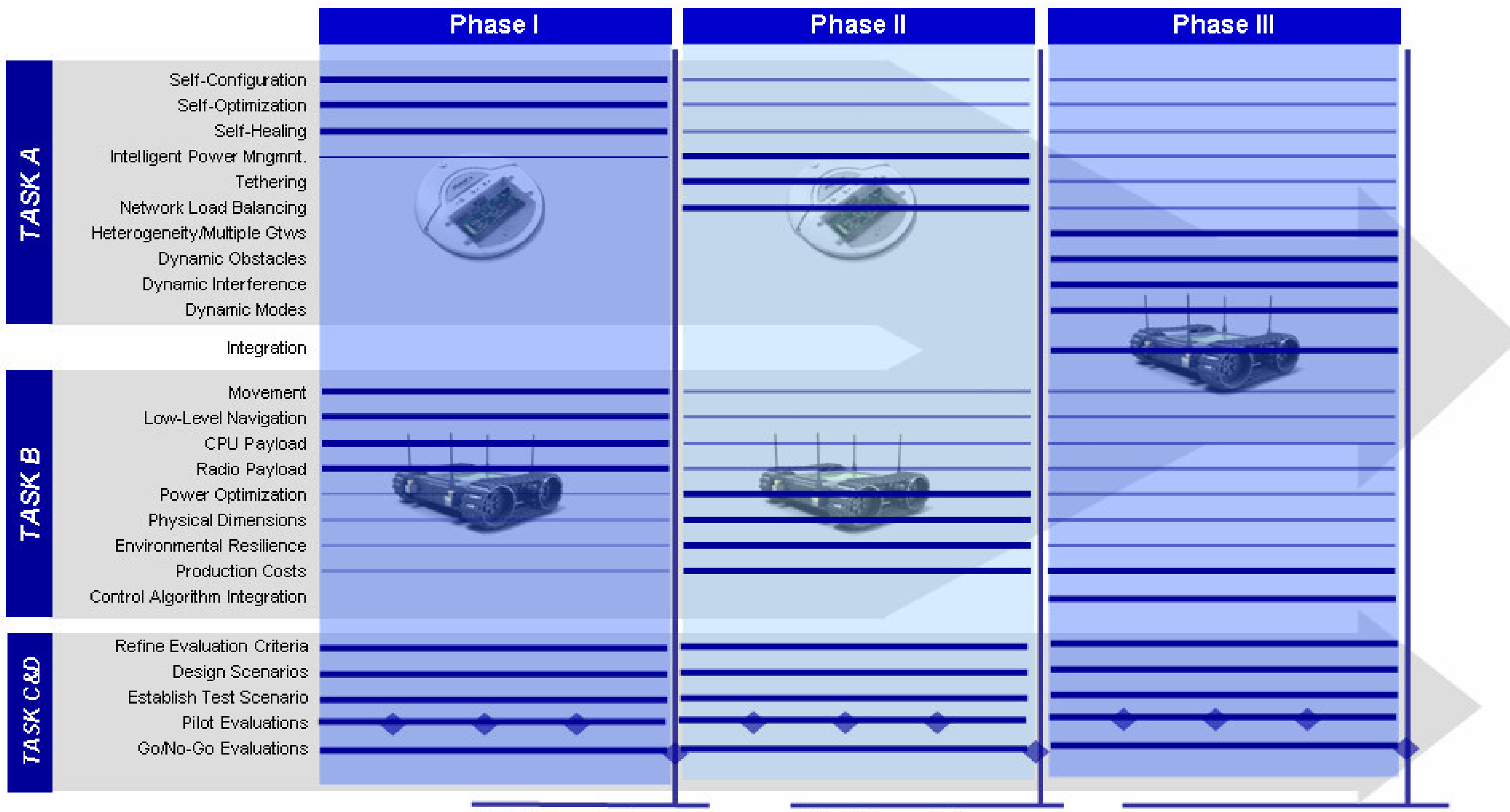
This is a subset of the information in the BAA.

Create a Robotic Platform to Support LANdroids Concept & The Software Developed in Task A

Task D – Robotic Platform Evaluation

- Expertise should include understanding of robotics, mechanical engineering, and power.
- Duties include but are not limited to:
  - Designing test scenarios and evaluation plans.
  - Locating and securing a proper site(s) for testing.
  - Defining appropriate benchmark tests for the processor and radio.
  - Assisting in selection of a MANET protocol for Task A during Phase 1.
  - Conducting pilot evaluations and end-of-phase evaluations.
  - Supplying all necessary equipment for evaluation measurement.
  - Reporting results to DARPA.

Programmatics - Program Phases



- Task A demonstrations:
  - Self-Configuration
  - Self-Optimization
  - Self-Healing
- Task B demonstrations:
  - Movement
  - Low-Level Navigation
  - Radio/CPU Payloads

- Task A demonstrations:
  - Tethering
  - Intelligent Power Management
  - Power Mgmt Protocols
- Task B demonstrations:
  - Power Optimization
  - Physical Dimensions
  - Environmental Resilience

- Task A demonstrations:
  - Multiple Gateways / Heterogeneous
  - Dynamic Obstacles/Interference
  - Programmable Objective Function
- Task B demonstrations:
  - Environmental Resilience
  - Production Costs

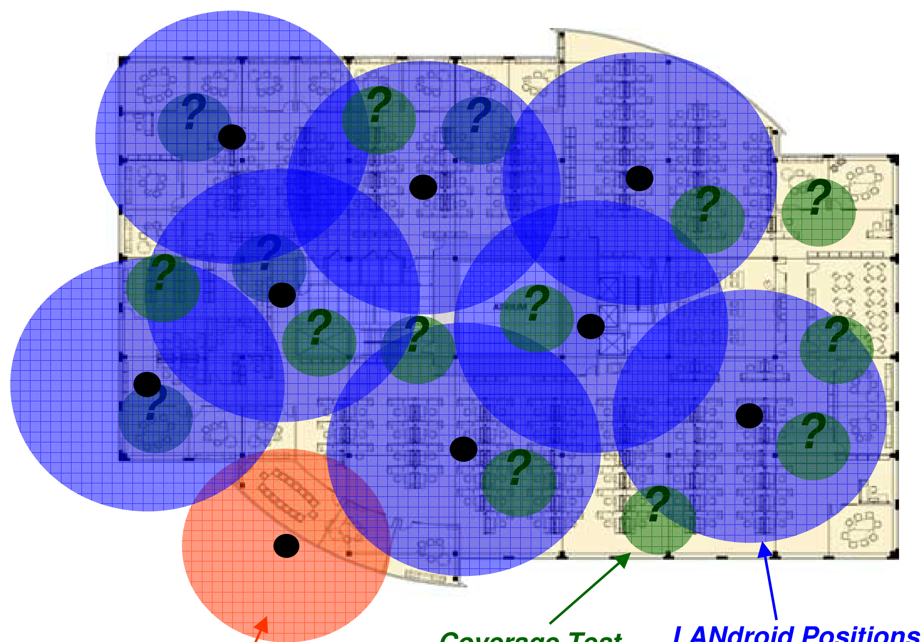
See The BAA For The Progression Of Capabilities Across Phases

Programmatics – A Word On Task A Metrics

- Metrics:
  - –Overall system performance:
    - **Coverage Percentile:** % of test points connected to gateway.
      - –Throughput >= 1Mbps, latency < 500 millisec.
    - **Longevity**: amount of time until 10-50% test points lose connection to gateway.
  - –Communications optimization:
    - **Throughput, Latency:** performance from each LANdroid to gateway.
  - –Coordination costs:
    - **Convergence Time:** initial & reconvergence post change.
    - **Message Overhead:** # msgs & # bytes averaged over t.

Phase	# LANdroids # of Floors	Capabilities, Weights, and Metrics (weights for weighted average ranking of teams)
I	10 LANdroids 1 Floor	Capability: Self-configuration (30%). Metric(s): coverage percentile (Auto-drop & ad-hoc).
		Capability: Self-optimization (10%). Metric(s): throughput & latency (concurrent).
		Capability: Self-healing (30%). Metric(s): coverage percentile (post node death).
		Property: Coordination costs (30%). Metric(s): (re)convergence time, # msgs, # bytes.
II	15 LANdroids 2 Floors	Retest all Phase I capabilities with 2 floors and 15 LANdroids (23%).
		Capability: Intelligent Power Mgmt (23%). Metric(s): longevity.
		Capability: Tethering (23%). Metric(s): coverage percentile.
		Capability: Customized network load balancing for power (8%). Metric(s): longevity.
		Property: Coordination costs (23%). Metric(s): (re)convergence time, # msgs, # bytes.
III	50 LANdroids 3+ Floors	Retest all Phase I & II capabilities with 3+ floors and 50 LANdroids (24%).
		Capability: Heterogeneity & multiple gateways (25%). Metric(s): coverage percentile.
		Capability: Dynamic obstacles (13%). Metric(s) coverage percentile sampled over t.
		Capability: Dynamic interference (13%). Metric(s): coverage percentile sampled over t.
		Capability: Programmable objective function (5%). Metric(s): boolean check.
		Property: Coordination costs (20%). Metric(s): convergence time, # msgs, # bytes.

Read the BAA – This Chart Breaks Down Capabilities, Tests, Phases



Programmatics – A Word On Task B Metrics

- Progression across the phases in requirements.

- Phase I –
  - Fundamental platform requirements:
    - Size – not required to meet 1,000cm^3 and 1,000g spec.
    - Robustness – no formal stress tests but will be tested in typical urban setting.
    - Inexpensive – not required to meet $100/platform but should submit component costs.
  - Basic capability requirements:
    - Movement –yes, 0.5m/sec over various surfaces.
    - Simple behaviors – yes, e.g., low-level navigation to return within-a-threshold.
    - Power – yes, demonstrate movement, comms, navigation. 5 hours target.
  - Platform payload requirements:
    - Processor – yes, e.g., demonstrate on a basic LANdroid algorithm and standard benchmarks concurrently with radio and autonomous navigation.
    - Radio module – yes, verified in LOS and NLOS.

Read the BAA

Important To Remember

- Read the BAA.
  - Read the FAQ – it is updated regularly.

- Email questions to **baa07-46@darpa.mil**

- Initial closing is August 16, 2007 @ 12:00pm ET.

- We're looking forward to your proposals!